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Risk Management: Potential for U.S. Microbreweries

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We investigate the potential to develop hedging strategies for firms in the U.S. microbrewing sector. We test for statistical relationships between cash prices for hops and barley, and futures prices for two classes of wheat and corn to determine whether price relationships are such that cross-hedging hops and barley with existing futures contracts appears feasible. We test for stationarity in prices, and for co-integration relationships between the brewers' inputs and commodity futures prices. We then use regression analysis to calculate hedge ratios for brewer inputs. Results indicate cross-hedging opportunities for small breweries may exist.

Key words: Beer, Commodities, Cross-Hedge, Minimum Variance Hedge Ratio, Vector Error Correction Model

There is substantial literature focused on hedging agricultural commodities (see, for example, Garcia and Leuthold, 2004, and Zapata and Fortenbery, 1996). However, to our knowledge, there has been little or no research focused on hedging primary inputs for the brewing industry: malting barley and hops. This is surprising given the rapid growth of the craft beer sector over the past 20 years (Carroll and Swaminathan, 2000; Brewers Association, 2016a; Tremblay, Iwasaki, and Tremblay, 2005).[1]

One concern microbrewers face is unexpected changes in ingredient prices that impact their costs of production. Although some input purchases might be forward priced with wholesale suppliers, for the most part the small size of many craft breweries exposes them to price risks. Unexpected increases in input prices without the ability to pass these through to output prices results in significant margin risks (Wilson, Nganje, and Wagner, 2006). Like many producers of consumer goods, brewers face difficulty in passing input price changes through to consumers, at least in the short run. Given the proliferation of

[1] One key challenge to estimating relationships among prices and hedging ratios for breweries is that most market transactions on hops between merchants and brewers are through private sales or contracts. Hence, there are no publicly available price data on hops by variety consistently collected over time. We discuss one price series for hops in more detail in the data section and subsequent limitations in the conclusions.

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beer producers, we can expect a consumer market that exhibits a relatively high elasticity of demand, thus any significant price increase by an individual brewer on the output side could result in a substantial decrease in sales.

As the craft brewing sector has grown, derived demand for different types of hops and malts has also evolved. Given the price volatility exhibited in most grain markets it is useful to investigate risk management opportunities in brewery feedstock procurement. Small brewers can improve survival prospects if they can find ways to minimize their exposure to input price risks. Unexpected increases in prices for commodities purchased in fixed proportions, based on the type of beer produced, without the ability to pass these forward, puts brewers at risk in times of increased input scarcity. For instance, with the growing sales of craft beers, hops prices have escalated in recent years, exposing some small brewers to significant profit risks.

Before constructing a hedge strategy for brewers, however, it is necessary to investigate price relationships between brewer inputs that have no direct futures pricing contracts (i.e., hops and malting barley) and commodities for which futures contracts do exist. A necessary condition for an effective hedge is an identifiable (and stable) relationship between the price of the commodity being purchased in the cash market and a commodity futures price traded on an organized exchange. In the case where the two commodities are identical in form (i.e., the cash commodity purchased and the futures contract traded are for identical commodities), a hedge is relatively straight forward. However, when the cash-purchased commodity is not identical to a commodity traded in the futures market, the price relationship is less clear. Nonetheless, if it can be determined that the price relationship is predictable, then basis risk (the difference between the cash and futures prices at the end of the hedge period) may still be less than the out-right cash price risk for the purchased input. When these opportunities exist, they are referred to as cross-hedges—a cash price for a non-futures-traded commodity can be cross-hedged on a futures contract for some other commodity. Identifying cross-hedging opportunities for craft brewers using futures contracts for commodities whose returns are correlated with the price changes in ingredients used to produce beer could help brewers implement strategies to minimize input price risks (e.g. Chu et al., 2009; Gaur and Seshadri, 2005; Wilson, Nganje, and Wagner, 2006).

Objectives and Data

Objectives

To examine whether the necessary conditions exist to allow for cross-hedging of brewers' inputs, we empirically examine price relationships between the primary inputs of brewers and established futures contracts for various grains. We explicitly look at price dynamics between hops and malting barley relative to futures prices for corn and both soft-red and hard-red winter wheat. These are presumed to be the commodities with the closet potential relationships to brewers' inputs since both corn and wheat are inputs in many beer recipes (in fixed proportions to malting barley and hops), and both also represent substitutes with barley in many farmers' planting decisions. Based on these findings, we then estimate optimal hedge ratios for various combinations of cash and futures price pairs examined (as outlined by Hull, 2015).[2] This is done by regressing changes in cash prices against changes in futures prices, and then using the estimated coefficients to calculate potential hedge ratios.

While the results are positive, this is the first study to examine hedging opportunities for microbrewers and, thus, should be interpreted as exploratory. The analysis is a bit constrained by data availability with respect to hops. Most hops transactions are private. The only publicly available data is collected by the Foreign Agricultural Service of the U.S. Department of Agriculture (USDA-FAS). This data is reported as an average quarterly price across all hops varieties, as opposed to prices for individual varieties. However, the results presented here suggest that it is worth pursuing additional research with less aggregated data. We are currently perusing that data directly from industry sources.

Data and Description

To test price relationships, we initially collected quarterly cash and futures price data from January 1972 to December 2011.[3] Futures prices come from the Commodity Research Bureau. We collect futures prices for soft-red wheat futures traded in Chicago, hard-red wheat futures traded in Kansas City, and corn traded in Chicago.

[2] There is an animal feed-grade barley futures contract traded at the Winnipeg Futures Exchange. However, we do not explicitly consider this contract due to the need to account for exchange rate variations. There is no futures contract for malting barley.

[3] We would like to use less aggregated data, but are constrained by the frequency of the available hops data. It is publicly reported as a quarterly series by USDA-NASS. We are working to collect less aggregated data directly from industry, but this data is not yet available.

Malting barley prices come from USDA's National Agricultural Statistics Service (NASS), and hops prices are taken from USDA-FAS. Prices for hops are export prices.[4] This is because most transactions between hops merchants and brewers are through private sales or contracts. Hops prices are quarterly data averaged across various hops varieties. Barley, corn, and wheat prices are aggregated to quarterly averages to be consistent with the hops prices reported by USDA. Descriptive statistics for all data used are presented in Table 1.

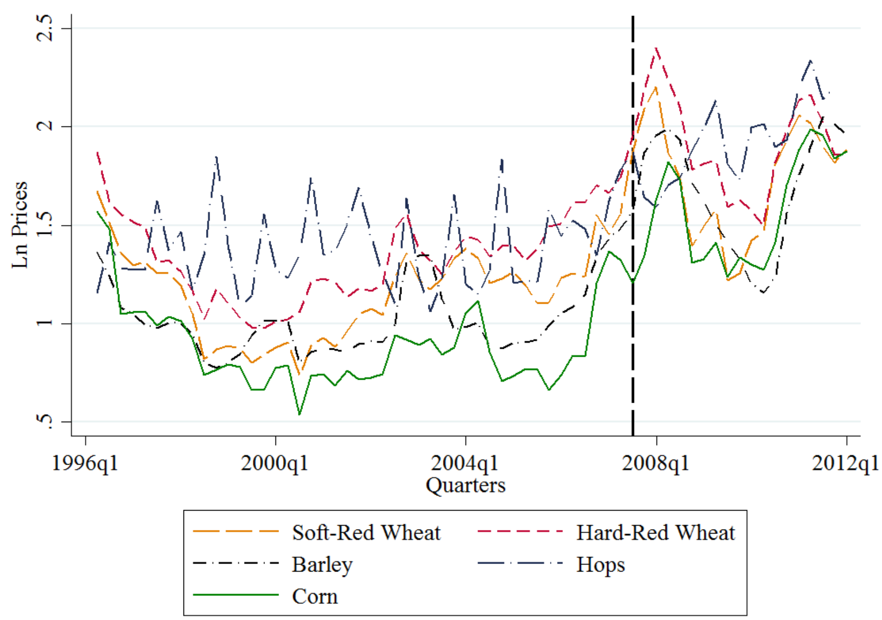

Figure 1. Price Series during the Study Period.

[4] The only publicly available, farm-level price series for hops in the United States collected consistently over time is completed by USDA-NASS, which reports an annual average price for hops that is not variety specific. Export prices are the closest to farm-level prices the authors could find with more frequent reporting than annual observations. However, it is important to note that they also are not variety specific. See Gabrielyan and Marsh (2016) for more details.

An examination of the data suggests several potential changes in price behavior over the entire sampled period. These shifts are likely due to changes in government policies that support farm-level prices for commodity producers, changes in macro-economic conditions, and changes in agricultural productivity (associated with technological development). As a result of these price shifts, we restrict our empirical analysis to span from 1996 to 2011 (Figure 1). This period corresponds to the emergence of the craft brewing industry, and the beginning of farm program provisions that are more market focused (i.e., the emergence of non-binding price support programs with increased emphasis on market-determined, farm-level prices as an explicit federal farm program). Additionally, we split the sample into two sub-periods: before and after the fourth quarter of 2007. This break coincides with increased emphasis on grain-based bio-fuels production at both state and national levels, and to a general increase in commodity price levels (Carter, Rausser, and Smith, 2016; Motamed, McPhail, and Williams, 2016). The split also coincides with the prelude to the Great Recession. In addition, it appears that relative price behavior between some commodities (for example, hops and corn) changed from being generally negatively correlated to positively correlated following 2007. The second sub-period also represents the period of greatest growth in the craft brewing sector. Note that we see higher prices and more volatility in the second sub-period across all commodities evaluated, as presented in Table 1.

Table 1. Commodity Price Summary Statistics.

Grain	Study Period (n = 63)				Sub-Period 1 (n=46)				Sub-Period 2 (n=17)			
	Mean (SD)	CV	Min	Max	Mean (SD)	CV	Min	Max	Mean (SD)	CV	Min	Max
Soft-Red Wheat	4.01 (1.62)	0.40	2.09	9.07	3.33 (0.89)	0.27	2.09	6.52	5.85 (1.73)	0.30	3.39	9.07
Hard-Red Wheat	4.80 (1.87)	0.39	2.65	11.03	3.98 (1.01)	0.25	2.65	7.07	7.03 (1.85)	0.26	4.47	11.03
Barley	3.57 (1.52)	0.43	2.17	7.77	2.87 (0.63)	0.22	2.17	4.78	5.49 (1.59)	0.29	3.19	7.77
Hops	4.95 (1.75)	0.35	2.89	10.39	4.15 (0.97)	0.23	2.89	6.57	7.11 (1.56)	0.22	4.91	10.39
Corn	3.17 (1.39)	0.44	1.71	7.31	2.53 (0.66)	0.26	1.71	4.82	4.93 (1.36)	0.28	3.45	7.31

SD = Standard Deviation. CV = Coefficient of Variation.

Of all commodities considered, corn is the most volatile over the study period, with a coefficient of variation (CV) of 0.44, and hops the least with a CV of 0.35. However, once the data is separated into the two sub-periods, soft-red wheat is the most volatile, with a CV of 0.27 and 0.30, respectively. The two cash crops, hops and barley, are the least volatile when the data is separated into the two sub-periods. An inspection of prices over the study period shows a general increase, with some correlation among individual commodity price changes.

Based on Figure 1, hops prices appear to be negatively correlated with prices of the three grains until about 2005 (close to the cut-off point between the two sub-periods indicated with the vertical line), and then moves in the same direction of the three grains in later years. These observations provide some anecdotal evidence that, in the more recent years, cross-hedging opportunities may exist for hops using grain futures. The change in price dynamics could be the result of significant growth in the micro brewing sector in later years (Brewers Association, 2016a). This growth has likely led to increased demand for inputs from microbrewers, and this, in turn, may have resulted in the hops market trading more like other commodity markets and less like a small niche market that may experience idiosyncratic behaviors.[5]

Empirical Approach

The analysis presented here closely follows the established literature on hedging in both commodities and securities markets (e.g., Howard and D'Antonio, 1984; Gemmil, 1988; Shapiro and Brorsen, 1988; Wolf, 2012). However, unlike much of this literature, a large part of our focus is on cross-hedging of non-futures-traded commodities not previously studied (i.e., hops and malting barley). The use of financial instruments to deal with inventory and feedstock risks is not new (Gaur and Seshadri, 2005; Chu et al., 2009; Kouvelis, Li, and Ding, 2009; Wilson, Nganje, and Wagner, 2006), but applications to the brewing sector are novel.

Our approach for testing price dynamics between the commodities of interest is to employ traditional multivariate time-series methods. We test for stationarity in the individual prices, and then, based on the results of the unit root analysis, we test for cointegration and estimate a set of vector error correction models (VECM). In general, the model results suggest that a necessary condition exists for a risk-efficient hedging program to be developed for brewers (see Zapata and Fortenbery, 1996, for a discussion of this in the context of cointegration).

We then estimate simple hedge ratios for each cash/futures price pair. Three sets of hedge ratios are calculated, one for each sub-period, and one for the entire sample period. This provides a robustness check as to whether market conditions have changed across the two sub-samples.

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[5] According to USDA-NASS, U.S. hops production increased 96 percent between 2007 and 2017.

Moving forward, we investigate the cross-correlations among the cash prices, and corn and wheat futures prices. In the case of barley, theory suggests that prices should be related to both corn and wheat prices. Barley can be a substitute for corn and wheat in production. According to Motamed, McPhail, and Williams (2016), there has been a trend toward switching to corn at the expense of wheat and barley production in response to changes in public policy and relative prices. The relationship between hops and grain prices is less clear a-priori, except that barley and hops are complements in the beer-making process.

A standard model in the commodities literature (Fortenbery and Zapata, 2004) is the vector autoregressive model (VAR), which controls for own and cross-price effects, as well as measures of causality in relative price changes (Sims, 1980). A standard representation is given by:

$$(1) \qquad \mathbf{y}_t = \nu + \mathbf{A}_1 \mathbf{y}_{t-1} + \ldots + \mathbf{A}_p \mathbf{y}_{t-p} + \mathbf{u}_t$$

where $\mathbf{y}_t$ is a $K \times 1$ vector of prices, ν is a $K \times 1$ vector of constants, $\mathbf{A}_1, \ldots, \mathbf{A}_p$ are $K \times K$ matrices of parameters to be estimated, K is the set of commodities considered, and p represents the number of time lags.

If individual commodity prices behave as non-stationary series, but prices for different commodities and different market locations respond to the same fundamental stimuli, then the prices from the different markets maybe co-integrated. That is, commodity prices move together and exhibit a long-run equilibrium. In this case, equation (1) would be a misspecification of the relationship because the first difference would be stationary (Engle and Granger, 1987). A VAR in first differences, although properly specified in terms of a covariance-stationary series, would not capture long-run tendencies (Davidson et al., 1978).[6] If this is the case, there is a vector of error-correction terms, of length equal to the number of co-integrating relationships, or co-integrating vectors, among the series.

Based on unit root tests (available from the authors), it was determined that the commodity prices modeled here do, in fact, behave as non-stationary series. As a result, and consistent with previous literature (Fortenbery and Zapata, 2004), we employ a VECM to control for the shared common stochastic trend, if it exists:

[6] The VAR model only expresses the short-run responses of prices to any innovations in each commodity market.

(2) $$\Delta y_t = \nu + \prod \mathbf{y}_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta \mathbf{y}_{t-i} + \epsilon_t$$

where, $\prod = \sum_{j=1}^{j=p} \mathbf{A}_j - I_k$ and $\mathbf{\Gamma}_i = -\sum_{j=i+1}^{j=p} \mathbf{A}_j$ represents vectors of coefficients for the equilibrium relationships and long-run adjustment parameters, respectively.

We then calculate optimal hedge ratios for the pairs of cash/futures prices that exhibit co-integration. This is done by regressing cash price changes on futures price changes. The regression R^2 indicates hedging effectiveness (how much of the cash price variation is being managed by the hedge) (Hull, 2015).

Results

Following the literature, we test for co-integration using the Johansen trace test (Johansen, 1991). The Johansen test indicates 4 co-integrating vectors among the five variables (hops, malting barley, corn futures, and both soft- and hard-red wheat futures) in the first sub-period, and 3 co-integrating vectors in the second. Order-selection shows the optimal lag-length for the first sub-period (Q2:1996-Q3:2007) to be 8, and for the second sub-period (Q4:2007-Q4:2011) to be 2.[7]

To address the possibility of over-parameterization (a concern noted by one of the anonymous reviewers), we conducted diagnostic and sensitivity testing to ensure that we retain a parsimonious number of parameters for both period sub-samples. It is important to point out that we do not claim to have a definitive model or results, but that this is an exploratory analysis, restricted by data limitations.

In the first sub-period, we observe an inverse relationship between prices for hops and corn futures. There is also some weak evidence of an inverse relationship between wheat and corn futures. However, this behavior changes after 2007, providing evidence to support the hypothesis of structural change gained from visually examining Figure 1. In light of this, we present and discuss our results separately for the two sub- periods. In the interest of space, we do not directly report the VECM regression results, but these are available from the authors.

[7] Five information criteria were used to determine lag length: the Akaike Information Criterion (AIC), Final Prediction Error (FPE), Hannan and Quinn Information Criterion (HQIC), Schwartz Bayesian Information Criterion (SBIC), and the Likelihood Ratio test.

Table 2. Sub-period 1 VECM Summary Results (8 lags).

	Commodity	Effect on Grain [a]				
		Soft-Red Wheat	Hard-Red Wheat	Barley	Hops	Corn
Commodity	Soft-Red Wheat	–	+	*NE*	*NE*	*NE*
	Hard-Red Wheat	*NE*	*NE*	+	*NE*	*NE*
	Barley	+	+	*NE*	–	+
	Hops	+	–	*NE*	*NE*	+
	Corn	+	–	+	+	+
	Long-run causality [b]	*NE*	✓	✓	✓	✓
	Short-run causality [c]	*NE*	*NE*	✓	✓	*NE*

No effect (NE); Negative Feedback (–); Positive Feedback (+).
✓ denotes effect is present. [a] A positive, negative, or no effect is based on the sign of stastistically significant coefficients. [b] Based on having at least one statistically significant long-run adjustment parameter. [c] Based on the Granger Causality Test reported in Table 3.

Sub-period 1 (Q2:1996 to Q3:2007) VECM Results

Results from testing for co-integrating relationships indicates the existence of an equilibrium relationship between soft-red wheat futures, hard-red wheat futures, corn futures, and cash prices for both barley and hops. This implies a long-run relationship across the major ingredients used in the production of beer, and corn and wheat futures prices. Market adjustments in response to shocks to individual commodity prices range from 1 to 6 periods (results available from the authors). Results suggest barley prices are influenced by (or respond to changes in) wheat, corn, and cash hops prices. A summary of the empirical results is presented in Table 2.

Results from the long-run adjustment parameters indicate that, when barley prices are shocked, the hops price quickly adjusts to the barley price level within the same quarter. More importantly, we find the existence of a long-run equilibrium between malting barley cash and corn futures prices. This suggests corn futures contracts could be effective in reducing malting barley price risks. There is also short-run feedback from soft-red wheat futures to barley, as well as feedback from hard-red wheat. There is negative feedback from hops to barley prices (not unexpected, given they are complements in the brewing process). In general, malting barley prices are *Granger caused* by the other commodity prices at a 5% level of significance (Table 3).

Table 3. Granger Causality Test Results.

Commodity	First Sub-period			Second-Sub period		
	χ^2	p-value	Result	χ^2	p-value	Result
Soft-red wheat	4.00	0.406	Accept H_0	16.10	0.003	Reject H_0
Hard-red wheat	2.89	0.576	Accept H_0	37.80	0.000	Reject H_0
Barley	12.81	0.012	Reject H_0	10.32	0.035	Reject H_0
Hops	14.85	0.005	Accept H_0	15.30	0.004	Reject H_0
Corn	5.81	0.214	Accept H_0	26.01	0.000	Reject H_0

According to the long-run adjustment parameters, when hops prices are shocked they quickly adjust back to soft-red wheat prices. We also find a positive influence between hops and corn prices.

Hops prices are *Granger caused* by the other commodity prices at a 1% level of significance. This is somewhat unexpected given the relatively small size of the hops market compared to grains, but encouraging in terms of developing a potential hedging program for hops.

Sub-period 2 (Q4:2007 to Q4:2011) VECM Results

As expected, we find the existence of an equilibrium relationship among the beer input commodities and futures in the second sub-period as well. There is a positive influence from the equilibrium relationship with respect to hops and a negative relationship with respect to corn. That is, the percent change in soft-red wheat, hard-red wheat, and barley prices are above the equilibrium value for hops and below the value for corn. Specific relationships are presented in Table 4.

Table 4. Sub-period 2 VECM Summary Results (2 lags).

Commodity	Effect on Grain [a]				
	Soft-Red Wheat	Hard-Red Wheat	Barley	Hops	Corn
Soft-Red Wheat	–	+	*NE*	+	*NE*
Hard-Red Wheat	–	+	*NE*	+	*NE*
Barley	–	+	*NE*	*NE*	–
Hops	–	+	*NE*	+	*NE*
Corn	–	+	*NE*	+	*NE*
Long-run causality [b]	✓	✓	✓	✓	✓
Short-run causality [c]	✓	✓	✓	✓	✓

No effect (NE); Negative Feedback (–); Positive Feedback (+).
✓ denotes effect is present. [a] A positive, negative, or no effect is based on the sign of stastistically significant coefficients. [b] Based on having at least one statistically significant long-run adjustment parameter. [c] Based on the Granger Causality Test reported in Table 3.

Tests reveal short-run causality across all commodity markets in the second sub-period. This period reveals stronger relationships compared to the previous period, with only the barley market appearing to not affect other commodities.

According to the long-run adjustment parameters, when soft-red wheat prices are shocked, the average prices for hops and corn quickly adjust (within 1 period). Barley prices also adjust to changes in soft-red wheat prices, but the lag is longer (up to 3 periods). In addition**,** the long-run adjustment parameters suggest that, as hard-red wheat prices are shocked, barley prices will adjust toward hard-red wheat at about the same speed they adjust to shocks in soft red wheat prices.

Interestingly, when hard-red wheat prices are shocked, they actually adjust back towards the hops price. Further, short-run causality tests suggest that grain prices *Granger cause* changes in hard-red wheat prices.

In the short-run, hops prices receive negative feedback from soft-red wheat prices, and positive feedback from hard-red wheat. This positive relationship between hops and hard-red wheat may be driven by a decrease in the area harvested for both grains starting in 2008, possibly contributing to similar price dynamics. (USDA-NASS data also show a reduction in wheat operations with harvested area during this period). On the other hand, the negative relationship between soft-red wheat and hops may be due to the price dynamics between soft- and hard-red wheat. In general, futures price changes *Granger cause* changes in hops and malting barley prices in the short run.

Discussion

Despite covering a shorter time horizon (4 years vs. 11 years), findings suggest 3 longer-run equilibrium relationships among the commodities in the second sub-period, compared to 4 in the first. Short-run feedback is more immediate in the second sub-period. Thus, market impacts across the commodities appear to have become stronger and more time-concentrated since 2007. One interesting finding is the loss of the effect of barley price changes on other markets, and the increased affect of hops price changes in the second sub-period.

Another interesting finding is the feedback effect that corn prices have on barley in the second sub-period. Since late 2007, corn futures prices do not exhibit any feedback effect from barley in the short run. According to the co-integration coefficient, there is a negative equilibrium relationship between corn and barley during this time. On the other hand, changes in barley prices have no effect on corn. A possible explanation for this effect is that corn can be considered a substitute food grain, but barley would not be considered a substitute for fuel (Gold and Thompson, 2004). Thus, as farmers opt to shift their production capacity to corn due to more attractive market opportunities, there is a positive impact on barley prices due, in part, to expected scarcity as resources are shifted from barley to corn production.[8]

This may have important implications for craft beer producers who rely on smaller contracts or spot prices to source their inputs. As more land is devoted to corn production, greater pressure is put on prices for the commodities used in beer production.

Exploratory Hedge Ratios

There are multiple methods for estimating optimal hedge ratios. As an initial test of hedging potential, we estimate a minimum variance hedge ratio (MVHR). This involves calculating the coefficients of correlations between cash price changes and futures price changes, and then multiplying the correlation coefficient by the ratio of the standard deviation of cash price changes to the standard deviation of futures price changes (Hull, 2015). Specifically, the MVHR is calculated as:

(3) $$h^* = \rho \frac{\sigma_C}{\sigma_F} = \frac{cov_{CF}}{\sigma_F^2} = \beta$$

where σ_C is the standard deviation of cash price changes, σ_F is the standard deviation of

[8] In North Dakota alone, for example, barley planting fell by 1 million acres between 2007 and 2017, while corn acres planted increased by 1.1 million acres (USDA-NASS, 2017).

futures price changes, and ρ is the coefficient of correlation between cash and futures price changes, cov_{CF} is the covariance between cash and future price changes, and β is the regression coefficient.

If a futures hedge completely covers all cash price risks (i.e., there is no basis risk), then ρ =1 and $\frac{\sigma_C}{\sigma_F}$ =1, thus h^* =1. This, of course, is quite rare even when the cash and futures prices are for identical commodities. In the cross-hedge cases considered here, h^* can be expected to deviate significantly from 1, and will be a function of both the estimated parameter, ρ, and the relative behaviors of cash versus futures price changes. For example, even if ρ = 1, but the standard deviation of futures price changes is twice the standard deviation of cash price changes then the minimum variance hedge ratio will be 0.5.

The effectiveness of the hedge (i.e., the percentage of cash price variation the hedger is insulated from as a result of implementing the hedge) is represented by the R^2 of the regression. The higher the R^2, the greater the reduction in cash price risk because of the hedge.

Table 5 reports the results and optimal hedge ratios for barley and hops using the three different futures contracts considered. Each cash and futures price regression is tested using the Durbin-Watson test for autocorrelation. Where autocorrelation is found, we re-estimate the regression using the Cochrane-Orcutt procedure (Wooldridge, 2012). In general, the results suggest that hedging opportunities exist for managing brewer input price risks.

One important difference between the results for barley and hops is the lack of statistical significance in the estimated coefficients for the hops regressions. The R^2 value for all hops regressions are also relatively low compared to the barley regressions, and hops exhibits high variance. With the sample separated into the two sub-periods, we find the ability of futures contracts to hedge price risks differs. For the full sample, hard-red wheat would protect almost 15% of the price risks related to barley, while corn would protect 32%. In contrast, hard-red wheat would protect less than 0.5% of the hops risks, but still more than corn. However, for the second sub-period, the MVHR suggests hard-red wheat only protects about 6% of the price risks for barley, while corn futures cover almost 40%. For hops in the second sub-period, there is no statistical relationship between hard-red (covering about 2% of cash price variations) and soft-red wheat (covering almost 4% of cash price variations). This change in hedging positions by time suggests the historical sample length considered can be critical in developing hedge programs for craft brewers.

Table 5. Barley and Hop Price Return Regression on Futures Commodities.

	Corn			Hard-Red Wheat			Soft-Red Wheat		
	Beta	Std. Error	R^2	Beta	Std. Error	R^2	Beta	Std. Error	R^2
Barley [a]									
Full Sample	0.4330	0.0806	0.3249	0.2098	0.0654	0.1465	0.1749	0.0700	0.0942
Sub-Period 1	0.3500	0.0908	0.2567	0.2247	0.0770	0.1653	0.3063	0.0757	0.2759
Sub-Period 2	0.4368	0.1436	0.3978	0.1136	0.1175	0.0626	0.0597	0.1219	0.0169
Hops [a]									
Full Sample	-0.0243	0.2542	0.0002	0.0919	0.1811	0.0043	0.0866	0.1975	0.0032
Sub-Period 1	-0.4605	0.4318	0.0258	0.5286	0.3648	0.0465	0.2965	0.3744	0.0144
Sub-Period 2 [b]	0.2304	0.3576	0.0288	0.1232	0.2536	0.0166	0.2030	0.2777	0.0368

[a] Serial correlation was detected according to the Durbin-Watson test. Model estimated with the Cochrane-Orcutt regression. [b] Although no serial correlation was detected, the Cochrane-Orcutt regression performed better than the standard regression based on AIC and BIC scoring. The results correspond to the Cochrane-Orcutt regression.

For the full sample and second sub-period, corn performs best in protecting against barley price risks, followed by hard-red wheat, and with soft-red wheat being the least effective. In the case of hops, corn never dominates, with hard-red wheat performing better when the full sample is considered. In the first sub-period, hard-red wheat performs better than soft-red wheat, while in the second sub-period soft-red wheat does a better job managing hops price risks. However, in general, none of the individual futures contracts appears particularly effective in managing the price risk of hops.

Improvement of hedging performance might come from treating barley and hops as a single commodity. They are generally used in fixed proportions and, perhaps, weighing their relative risks in proportion to their use to create a single input and then implementing a single strategy for the combination, would improve overall hedging performance. Further, perhaps considering a portfolio of futures contracts would increase efficacy. Tejeda and Goodwin (2014) found that, accounting for time-varying correlations among the individual products hedged by a soybean processor, improved hedging performance and reduced overall hedging costs compared to treating each output individually.

Implications for Future Research

While hedge potential is identified based on the results presented, it should be noted that the results do involve some limitations. First, the level of data aggregation does not allow for a more refined measure with shorter-than-quarterly planning horizons. This is driven by the current availability of hops data. We are in the process of collecting less aggregated hops data directly from industry, and hope to increase the sample size and refine the results presented here using a finer grid of prices. In addition, the current hops data is aggregated across all varieties.

Anecdotal evidence gained through discussions with industry representatives suggests significant price variations across hops varieties, and different varieties are used for different beer styles. This suggests that optimal hedge positions for hops may be driven by the specific hops variety being purchased.[9]

Despite the data limitations, the results presented here do suggest work with less aggregated data is worth perusing. While the hedge ratios estimated here may not be directly applicable to a specific brewery, the analysis suggests that it is worth evaluating hedging opportunities with less aggregated data, and such work will likely lead to a better understanding of risk management opportunities for specific breweries.

Another issue relates to craft brewery size and the ability to institute and manage a hedge program. For a brewery to be considered a microbrewery, it must produce less than 15,000 barrels of beer per year (Brewers Association, 2016b). Bell's (a larger microbrewery in Michigan), produces around 12,000 barrels per year, or 3,000 barrels per quarter. One of its more popular beers is Two Hearted IPA. If we assume that the recipe for Two Hearted IPA is typical of Bell's input requirements, then it would require 232,500 pounds of malted barley and 20,667 pounds of hops per quarter (BeerSmith, 2016). Futures contracts for wheat and corn are traded in bushels. Converting the quarterly malting barley requirement to bushels yields 3,875 bushels of malted barley per quarter (a similar conversion can be made for hops, but the number will be much smaller given the smaller amount of hops in the recipe). Corn and wheat futures contracts are each for 5,000 bushels, thus the quarterly needs of a single brewer will likely be less than the size of a single futures contract. This suggests that, to benefit from hedging, breweries may have to cooperate in purchasing inputs. This could be done by forming buyers' cooperatives that source for several breweries; or, perhaps a new broker industry develops where brokers aggregate across several customers to source and then hedge inputs. This is currently done in the grain industry; grain elevators often offer farmers guaranteed prices for future delivery in amounts less than the size of an individual futures contract. They hedge their risk of over-paying farmers for future delivery by aggregating several farmers' forward contracts, and then implement a single futures market position to cover aggregate price risks going forward.

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[9] Zhang, Marsh, and Gent (2015) report a range of hops prices across varieties from a survey in 2012. There is hope more variety-specific price data on hops will become available from novel, web-based hops exchange platforms evolving in the industry to fill the information gap between hops merchants and brewers.

A final issue is the relatively simple and static nature of the hedge ratios calculated. Future research with less aggregated data will focus on developing a more comprehensive dynamic hedge program (similar to Tronstad and Taylor, 1990). The dynamic model being developed will account for transaction costs, margin management, and the simultaneous hedging of both malting barley and hops. In addition, it will allow for use of a portfolio of futures contracts to more comprehensively cover input price risk. The value of the work presented here is that it provides a rationale to pursue research on a more sophisticated hedging strategy; the positive results suggest that increased rigor in defining and measuring risk management potential will likely have a positive payoff.

Conclusions

The purpose of this work is to investigate whether potential cross-hedging opportunities exist for the major ingredients purchased by craft brewers. We first estimate VECM to investigate the price dynamics between hops and malting barley cash prices, and futures prices for both soft- and hard-red wheat, and corn. We find significant relationships between the prices considered, but these relationships have evolved over time. Most relevant to current craft brewers are the most recent price relationships. However, the analysis is constrained by the inability to use less aggregated data. For example, in the second period (Q4 2007-Q4 2011), much of the price adjustment happens "instantaneously," meaning within a single quarter. Yet with a finer price grid we may discover actual market adjustments are not instantaneous. Because the spot market for hops is relatively thin and prices are not regularly reported, it is not possible to tease out the actual price adjustments in less aggregate time currently, but we are working to collect less aggregated hops data directly from industry.

Despite the limitations of aggregated data, the fact that there is short-run causality and feedback between commodities markets is a good indicator of "influence" in the barley and hops markets from the commodities with active futures contracts. This provides evidence that the necessary price relationships exist to warrant the search for a hedging strategy for the craft brewing industry. However, given futures contract sizes and input needs of individual breweries, it is likely that hedging programs would need to be managed by larger buyers' cooperatives or private brokers, with the buying entity then providing cash forward contracts, in smaller volumes, to individual breweries.

Based on evidence that hedging might be feasible, we estimate minimum variance hedge ratios for both barley and hops using wheat and corn futures contracts. This exploratory analysis is not definitive, but it does provide evidence that hedging opportunities do exist. Future work is focused on incorporating transaction costs and accounting for the simultaneous hedging of malting barley and hops, in fixed proportions based on individual recipes, in a dynamic optimization model using less aggregated data. The major contribution of this paper is providing evidence that the effort associated with more rigorous modeling of hedging opportunities is worthwhile.

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